Back to Contents

Gas Cooled Fast Reactor (GFR)

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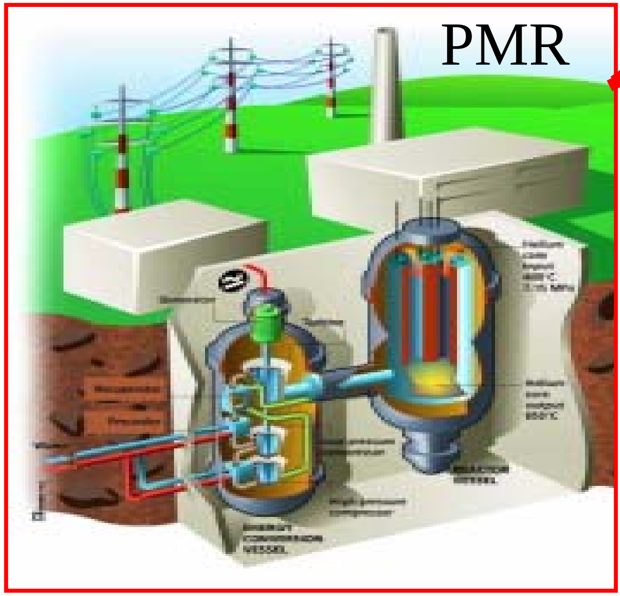
by

Frank Carre
CEA

Sequenced development of high temperature Gas cooled nuclear energy systems

R & D
- Fuel particles
- Materials
- He systems technology (850°C)
- Computer codes
- Fuel cycle



VHTR

> 950°C for VHT heat process

R & D
- VHT materials
- IHX for heat process
- ZrC coated fuel
- I-S cycle H2 production

GFR

Fast neutrons
Integral fuel cycle for high sustainability

R & D
- Fast neutron fuel
- Fuel cycle processes
- Safety systems

Rationale for GFR

- ***GFRs share the sustainability attributes of fast reactors***
  - ***Effective fissioning of Pu and minor actinides***
  - ***Ability to operate on wide range of fuel compositions ("dirty fuel")***
  - ***Capacity for breeding excess fissile material***

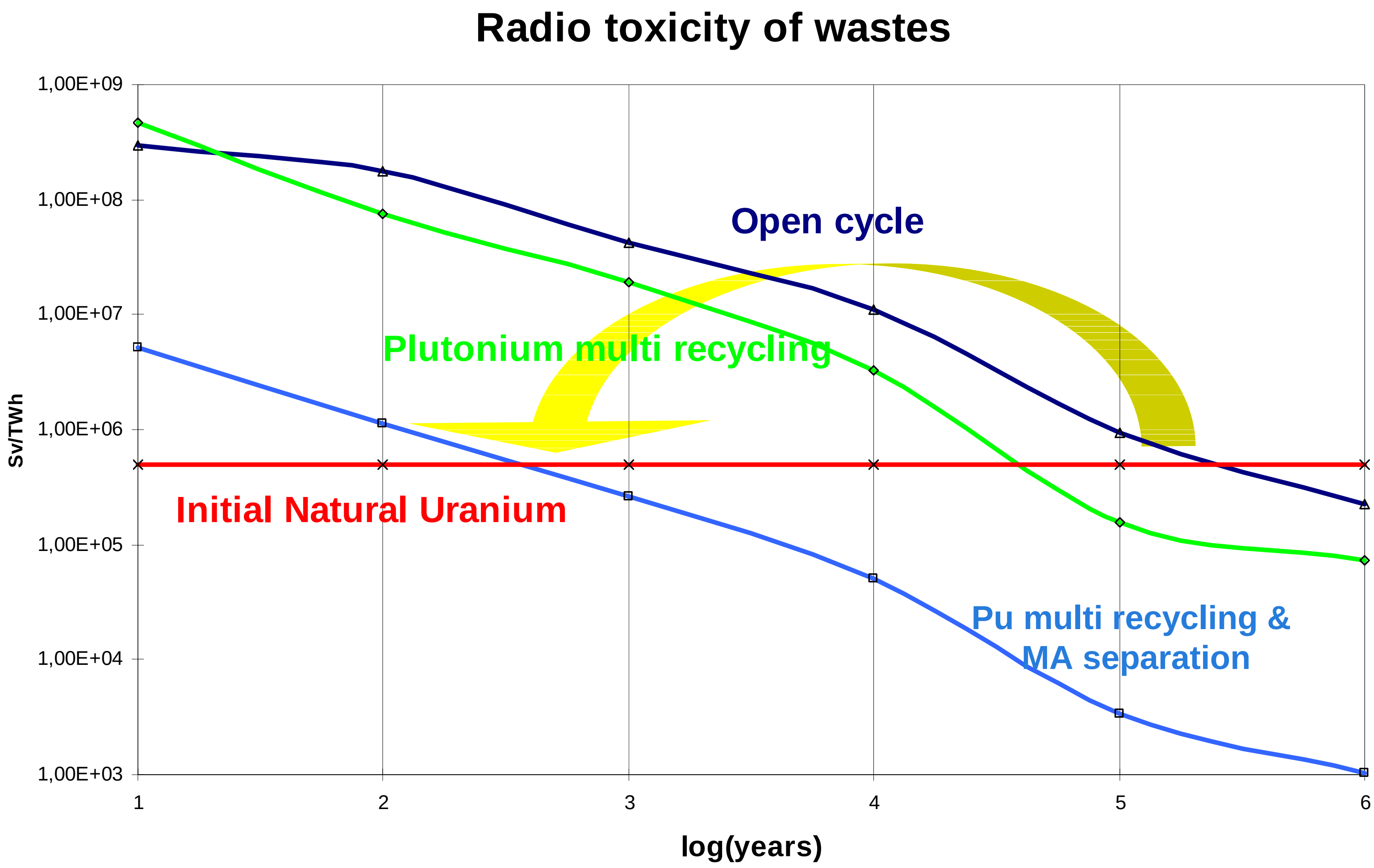
- ***Use of He coolant offers advantages of***
  - ***Ease of in-service inspection***
  - ***Chemical inertness***
  - ***Very small coolant void reactivity (<$ß_{eff}$)***
  - ***Potential for very high temperature and direct cycle conversion***

- ***High temperature potential opens possibilities for new applications, including hydrogen production***

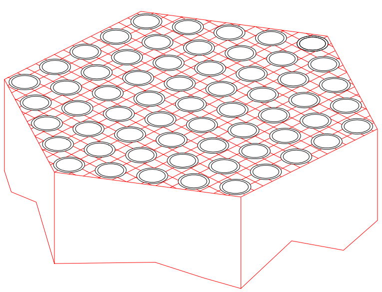
Main GFR Features

- ***Closed fuel cycle system with full TRU recycle***
  - ***Co-located fuel cycle facility***
- ***Hardened/fast spectrum core***
  - ***Reduced moderation relative to thermal GCRs***
- ***Direct Brayton cycle energy conversion***
  - ***He coolant, 850ºC outlet temperature***
  - ***Efficient electricity generation, potential for H_2 production***

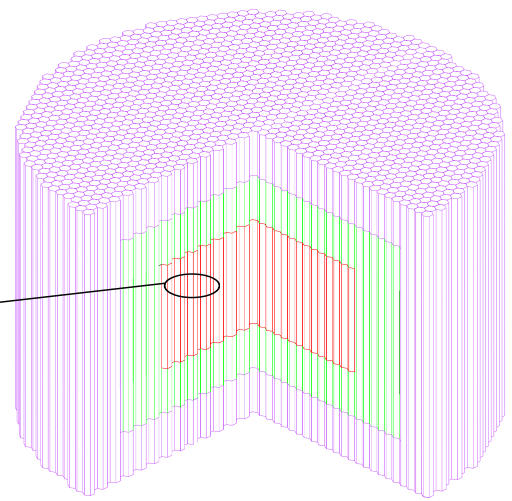
Potential improvement of LWR high radioactive waste management



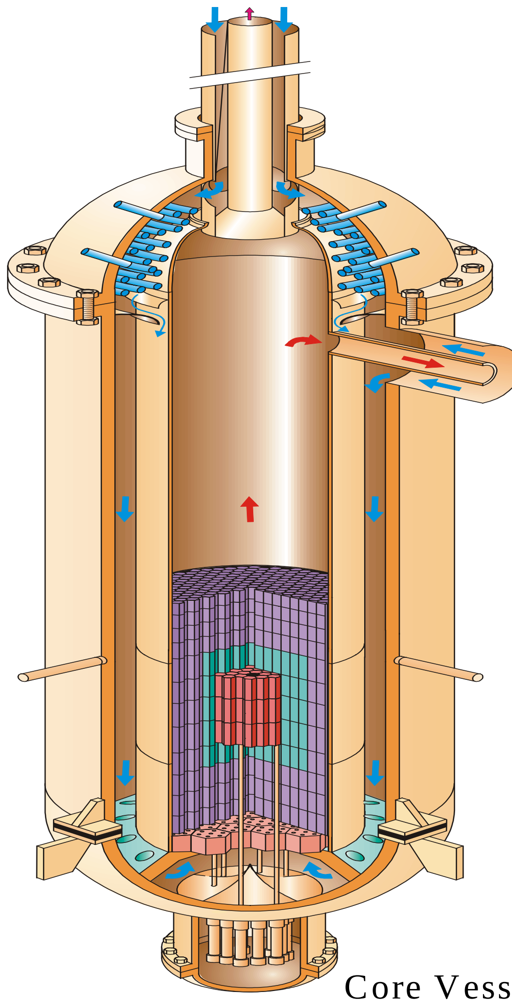
Gas-cooled Fast Reactor (GFR)
Example of candidate design options



Composite Ceramics
Fuel Element

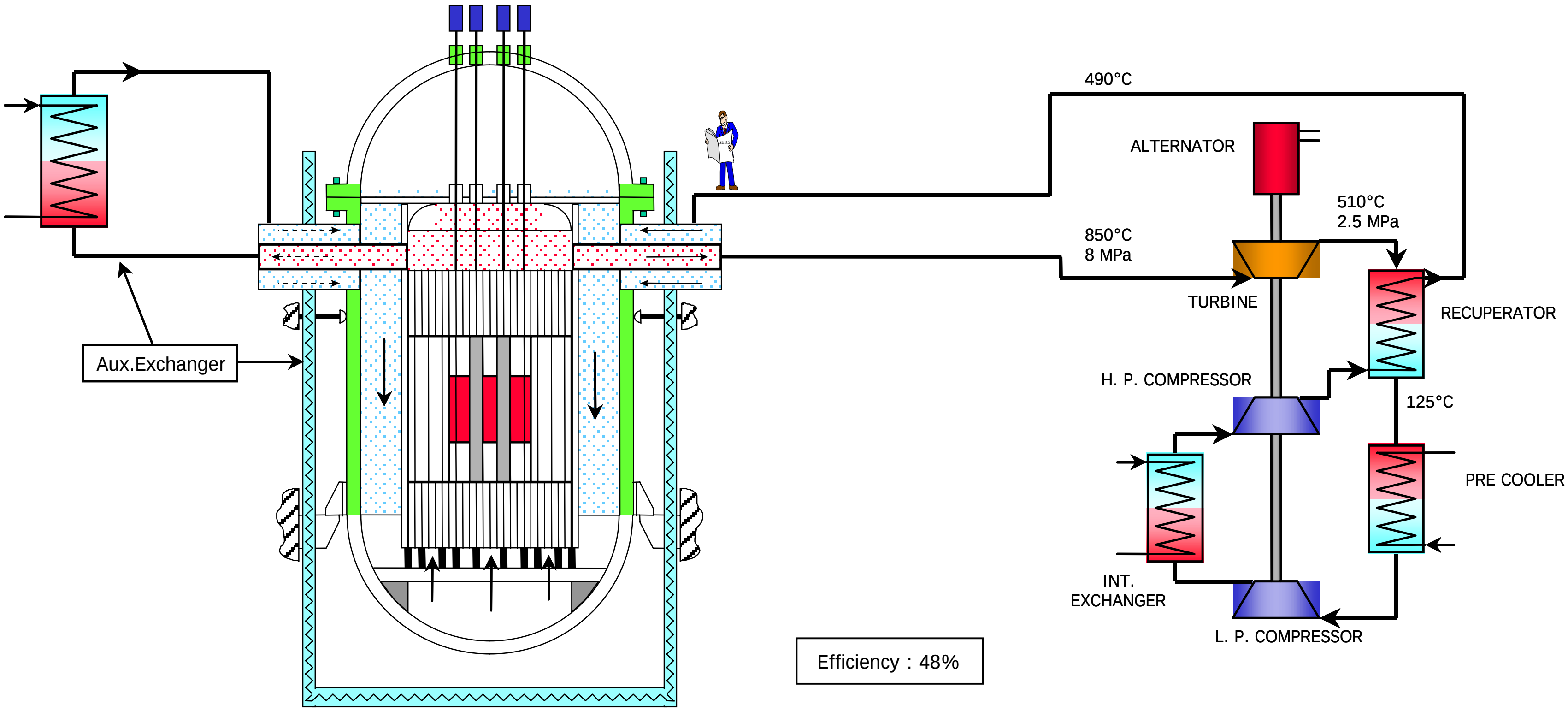


Core Lay-out



Core Vessel

GFR Plant Schematic



Reference GFR Parameters

System parameter	Reference value
Power plant	**600 MWth**
Net efficiency (direct cycle helium)	**48%**
Coolant pressure	**70 bar**
Outlet coolant temperature	**850 °C**
Inlet coolant temperature	**490 °C**
Nominal flow & velocity	**330 kg/s & 40 m/s**
Core volume	**10.9 m^3 (H/D ~1.7/2.9 m)**
Core pressure drop	**~0.4 bar**
Volume fraction (%) Fuel/Gas/SiC	**50/40/10 %**
Average power density	**55 MW/m^3**
Reference fuel compound	**UPuC/SiC (50/50 %)**
Breeding/Burning performances	**Self-Breeder**
In core heavy nuclei inventory	**30 tons**
Fissile (TRU) enrichment	**~20 wt%**
Fission rate (at %) ; Damage	**~5 at%; 60 dpa**
Fuel management	**multi-recycling**
Fuel residence time	**3 $\times$ 829 efpd**
Average Burn up rate at EOL	**~5 % FIMA**
Primary vessel diameter	**<7 m**

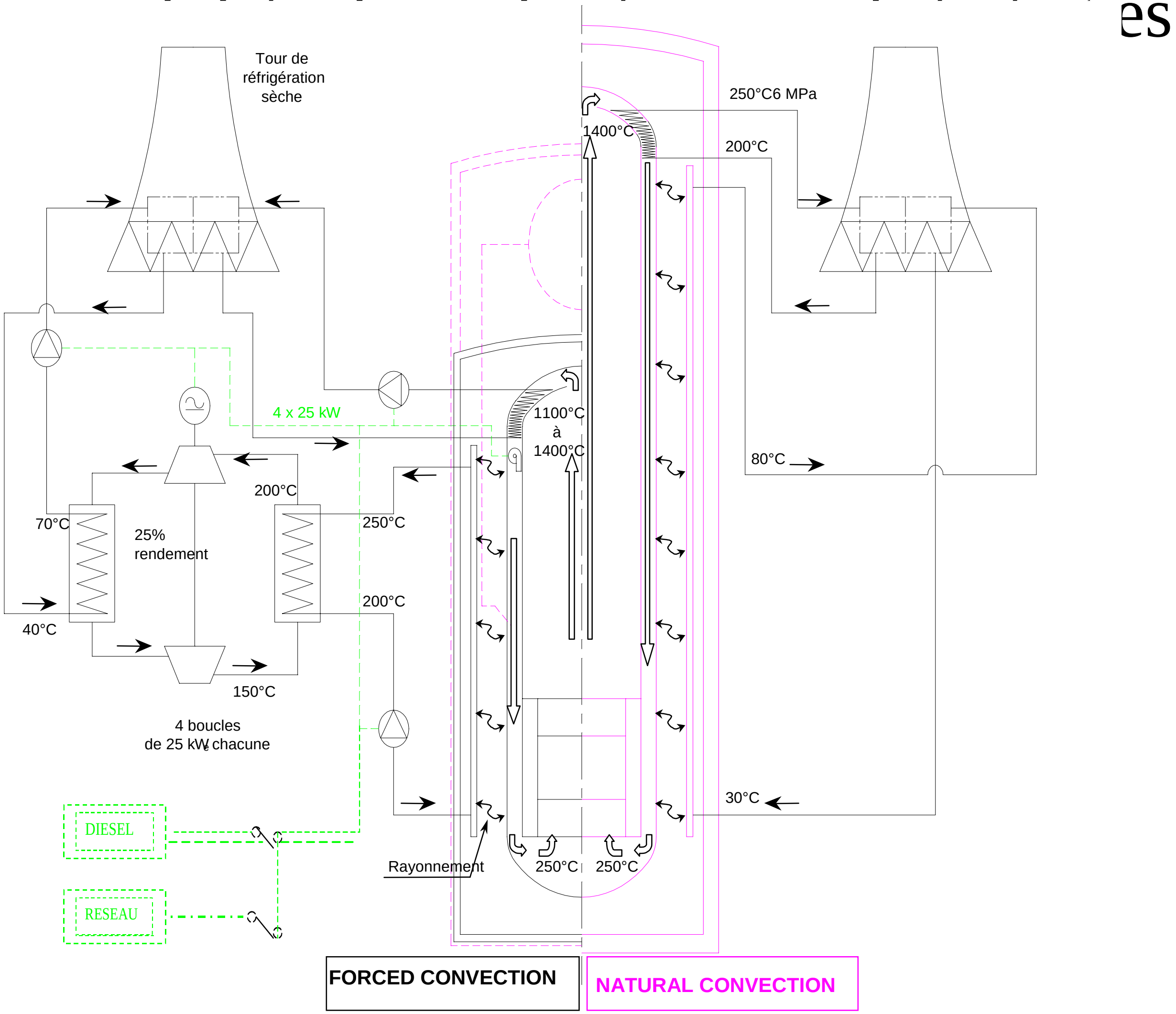
GFR R&D Needs

- ***Safety case difficult with low thermal inertia and poor heat transfer properties of coolant***
  - ***Reliance on active and "semi-passive" systems for decay heat removal***
  - ***Passive reactivity shutdown is also targeted***

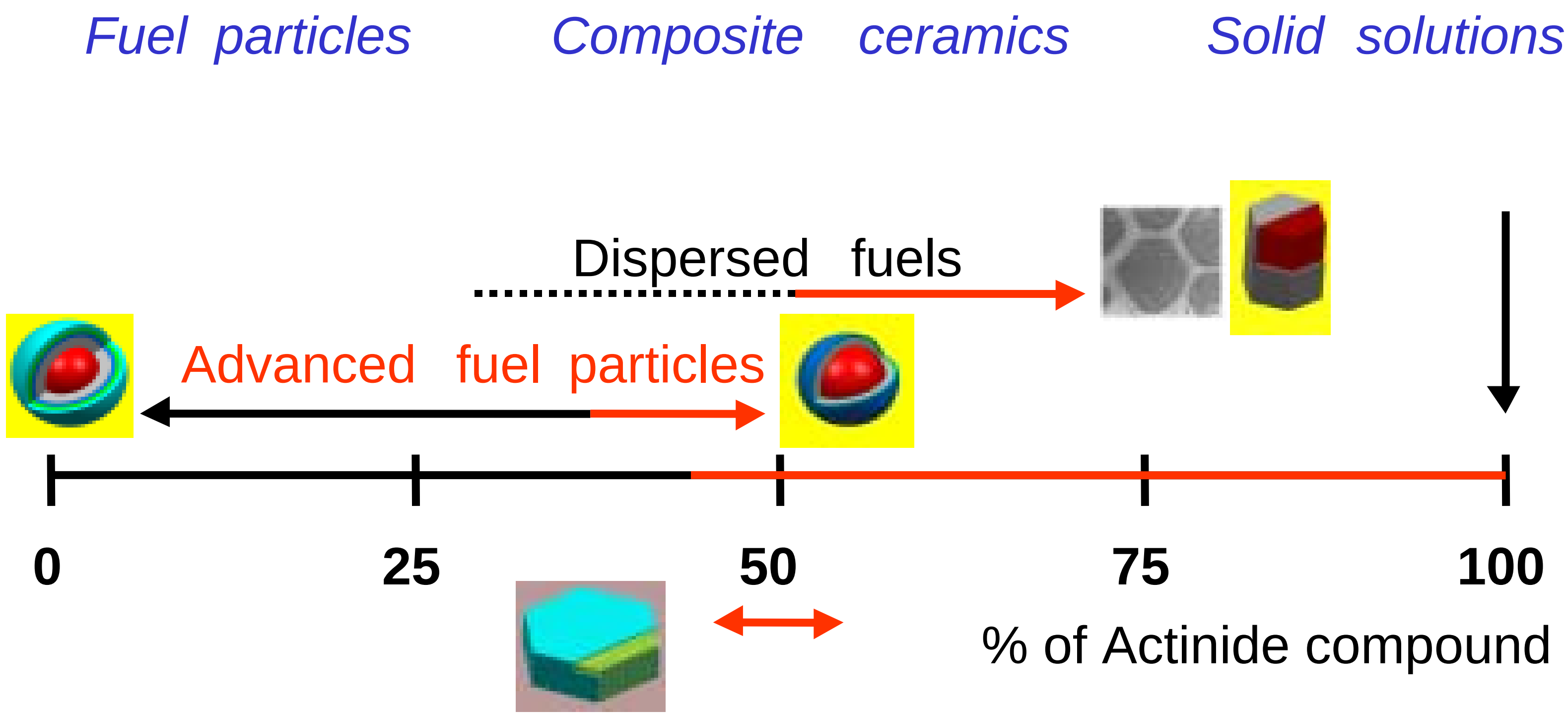
- ***High actinide-density fuels capable of withstanding high temperature and fast fluence***
  - ***Modified coated particle or dispersion type fuels, e.g.,***
    - ***(U,TRU)C/SiC***
    - ***(U,TRU)N/TiN***
  - ***Fuel pins with high-temperature cladding***

- ***Core structural materials for high temperature and fast neutron fluence conditions (ceramics***

GFR conceptual design studies

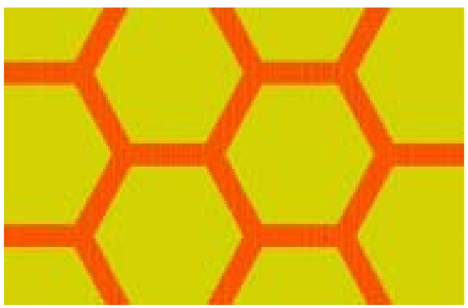


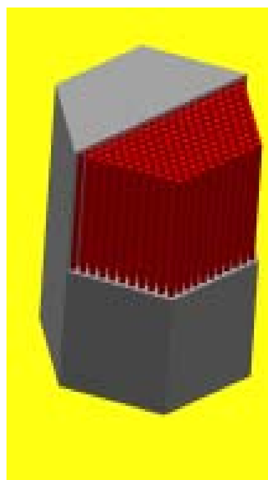
Gas cooled Fast Reactor (GFR) candidate fuel technologies

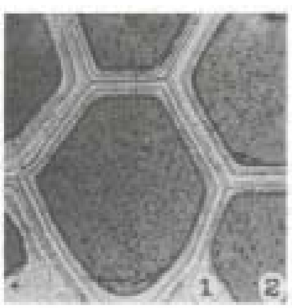


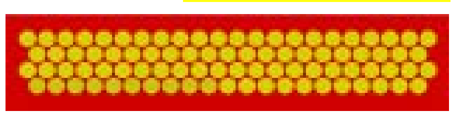
GFR candidate fuel technologies

- **Composite ceramics fuel with coated actinides elements and high actinides contents**
- **Achieve comparable performances with coated fuel particles in terms of high temperature resistance and FP confinement**
- **Preserve inert matrix coatings from generalized damage by fast neutrons and FP**



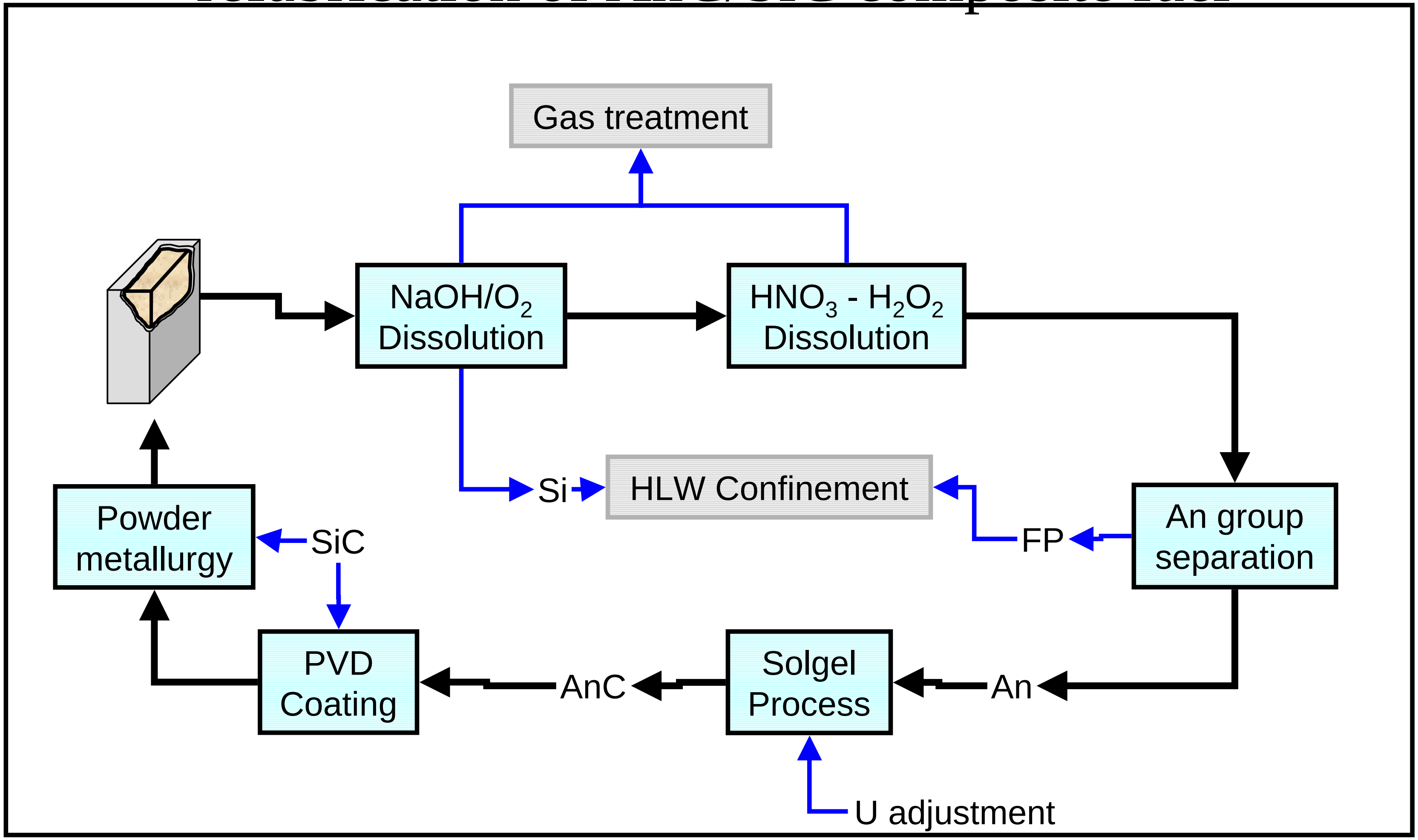






Neutrons	>1cm, collision
Fission products	10µm, ionisation
Particles α, He	20µm, ionisation
Recoil nuclei	<<1µm, collision

Exemple of processes for the treatment and refabrication of AnC/SiC composite fuel



GFR R&D Activities

- ***Basic approach***
  - ***Early focus on concept development emphasizing safety-in-the-design***
    - ***Characterize technical uncertainties***
    - ***Focus technology development***
  - ***Technology development (fuels, materials, etc.)***
    - ***Produce basic data to reduce uncertainties***
  - ***Confirmatory testing in follow-on phase***

- ***R&D scope elements***
  - ***Plant safety/concept development***
  - ***Fuel development***
  - ***Spent fuel treatment***
  - ***High temperature materials***
  - ***Safety/design calculation tools***

GFR Technical Issues

- ***Achievable degree of passive safety***
- ***Capability of materials to withstand targeted temperature and fast fluence conditions***
- ***Effectiveness of recycle technologies***
  - ***Actinide recovery factors***
  - ***Waste quantity and durability***
- ***Feasibility of economic design***